Evolution of the Black Hole -Bulge Relationship in QSOs

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ABSTRACT

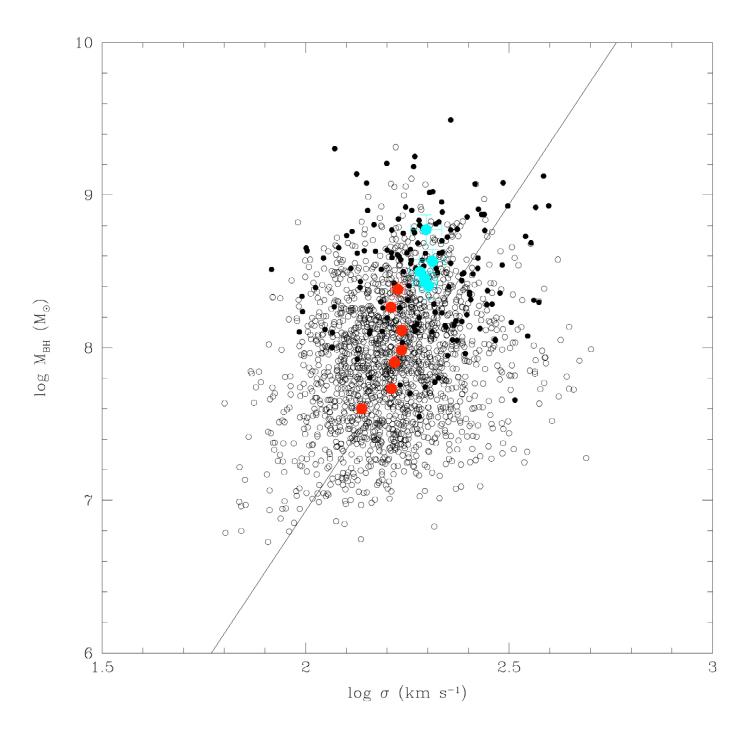
Quasars afford an opportunity to study the evolution of the black hole - bulge relationship, using the broad emission lines to estimate $M_{\rm BH}$. Results using AGN narrow emission lines as a surrogate for stellar velocity dispersion σ_* suggest some increase in $M_{\rm BH}$ at a given σ_* at $z \sim 1$. CO line widths indicate that at $z \sim 4$ to 6, giant black holes exist in undersized galaxies. The largest QSO black holes violate the standard $M_{\rm BH}$ - σ_* relationship.

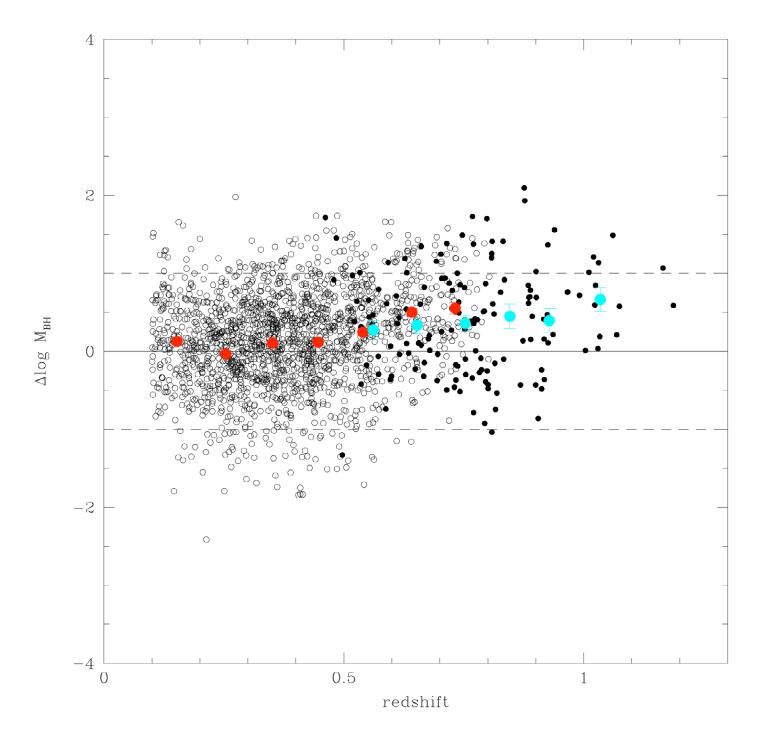
M_{BH} - σ Relationship in AGN

- Reverberation mapping gives BLR radius, scales as $R \propto L^{0.5}$ to $L^{0.7}$ (e.g., Kaspi et al. 2000, 2005; Bentz et al. 2006)
- Width of H β , Mg II, C IV gives $M_{\rm BH} = (10^{7.69} {\rm M}_{\odot}) v_{3000}^{2} L_{44}^{0.5}$
- Width of [O III] $\lambda 5007$ line is indicator of σ (Nelson & Whittle 1996, Nelson 2000, Boroson 2003, Bonning et al. 2005): $\sigma_* = \text{FWHM}$ of [O III] / 2.35. Needs confirmation for luminous QSOs.
- Study $M_{\rm BH}$ σ_* relationship (Ferrarese & Merritt 2000; Gebhardt et al. 2000; Tremaine et al. 2002): $M_{\rm BH} = (10^{8.13} {\rm M}_{\odot})(\sigma_*/200)^{4.02}$

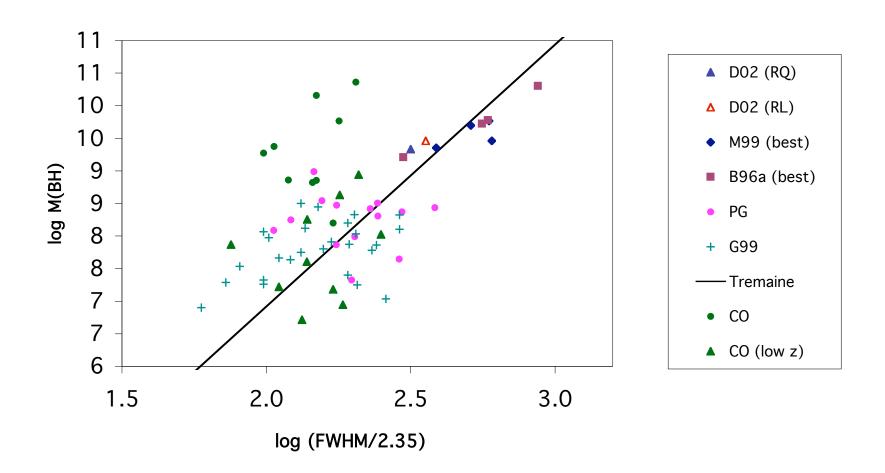
Evolution of $M_{\rm BH} - \sigma_*$

- Shields et al. (2003) find little change at z ~ 2 based on [O III] widths, for large BH in luminous QSOs.
- Salviander et al. (2006 submitted) find a 0.3±0.3 dex increase in $M_{\rm BH}$ at given σ_* at z ~ 1 using [O III] and [O II] for SDSS QSOs. Selection effects important.
- Peng et al. (2005) find BH mass 3 6 times too large for host mass using lensed QSOs at $z \sim 2$.
- Borys et al. (2005) find black holes much *smaller* than expected for stellar mass in SMGs at $z \sim 2$.
- Shields et al. (2006) use width of CO radio lines as surrogate for σ . At z > 4, giant black holes occur in QSOs with narrow CO lines suggesting modest galaxies.
- Can one get tight $M_{\rm BH} \sigma_*$ if black hole grows first?

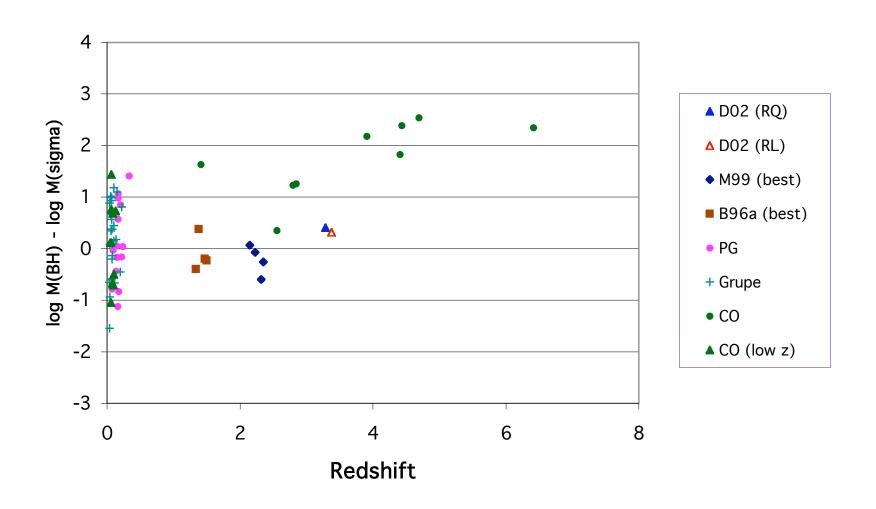




$M_{\rm BH}$ – σ for CO Quasars



Redshift Dependence



Host Galaxies of the Largest Black Holes

- Masses of QSO black holes from broad emission line widths call into question the normal $M_{\rm BH}$ bulge relationship (Netzer 2003; Wyithe & Loeb 2003).
- Most QSOs at redshift ~2 with $vL_v(5100 \text{ Å}) > 10^{46.6} \text{ erg s}^{-1}$ have $M_{\rm BH} > 5$ billion M_{\odot} . These masses are based on broad emission-line widths and are supported by the Eddington limit.
- QSO luminosity function gives ~6 such QSOs per comoving Gpc³. For a QSO lifetime of 50 million years, and a QSO epoch lasting 3 billion years, there should be ~10^{2.3} Gpc⁻³ former host galaxies with M>10^{12.4} M_{\odot} and σ > 500 km s⁻¹ by local relationships.

• Nearest such BH should be ~100 Mpc from earth, corresponding to largest cluster galaxies such as NGC 6166. These have $\sigma_* \sim 350$ km/s but luminosity is commensurate with BH *if* cD halo is included (see Lauer et al. 2006).